

# **THE U.S. DEPARTMENT OF ENERGY ALTERNATIVE FUEL HEAVY-DUTY VEHICLE PROGRAM**

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## **Abstract**

The Alternative Fuel Truck Application Program was initiated under the authority of the Alternative Motor Fuels Act of 1988. The goal of this program is to advance the use of alternative fuels in heavy-duty trucks. The DOE Office of Alternative Fuels is co-funding a national program encompassing over 400 heavy-duty alternative fuel vehicles. A key element of this program is data collection. The program is also collecting data from 48 heavy-duty alternative fuel demonstration vehicles that are operating on private or local government funding. Performance and emissions data on these types of vehicles indicates that certain advantages exist for alternative fuel operation over operation on conventional petroleum-based fuels when impending emissions regulations are taken into account. This paper will present a summary of this program as well as provide insight into planned future activities.

## **ACKNOWLEDGMENTS**

The Department of Energy's Alternative Fuel Heavy-Duty Vehicle Program wishes to express sincere appreciation to the engine and vehicle manufacturers, fleet operators and vehicle owner liaison organizations who contributed information to this report. Their continuing support of DOE's alternative fuel vehicle demonstration program has helped make it a success and it is their work, in large part, that has been responsible for the rapid advance of alternative fuels technology.

Thanks are also due to the staff at the National Renewable Energy Laboratory, particularly to Paul Norton, for providing fleet performance data from the Alternative Fuels Data Center (AFDC). Readers seeking more information on alternative fuel vehicle fleet operations are encouraged to use the resources of the AFDC. Contact Paul Norton (303) 275-4424.

Photographs of the natural gas engines are used by permission of the Cummins Engine Company and the Detroit Diesel Corporation. Other photos are by Warren Gretz of the National Renewable Energy Laboratory, except that of the ADM ethanol-fueled tractor which was provided by Archer-Daniels-Midland.

## **THE U.S. DEPARTMENT OF ENERGY ALTERNATIVE FUEL HEAVY-DUTY VEHICLE PROGRAM**

### **Introduction and Background**

The heavy-duty alternative fuel vehicle (AFV) efforts ongoing within the Federal government have largely resulted from the Alternative Motor Fuels Act (AMFA, Public Law 100-494), which was enacted on October 14, 1988. This act was the result of many long-term efforts to establish a large-scale demonstration of AFVs by the Federal government. Its stated purpose included two major components. First, it was aimed at encouraging development and widespread use of alcohols (both ethanol and methanol) and natural gas as transportation fuels. Second, AMFA was intended to encourage production of AFVs and AFV components. Perhaps almost as important however, were two unwritten purposes, which became major aims of the Federal program. These included obtaining operating experience (and generating useful operational data for decision-makers) and helping to build an alternative fuels infrastructure.

AMFA provided for AFV demonstrations in three major vehicle classes. Section 400AA called for DOE to establish a light-duty AFV demonstration, requiring that the "maximum number practicable" of light-duty vehicles (LDVs) acquired by the Federal government should be AFVs. As defined by AMFA, this covered alcohol and natural gas vehicles, both dedicated and "dual energy." Section 400CC called for an alternative fuel transit bus demonstration, which is being run by the U.S. Department of Transportation (DOT). Section 400BB called for a commercial truck applications program, focusing on the special needs of the truck and truck engine markets. This program is administered by the U.S. Department of Energy (DOE). It is this last class of vehicle (heavy-duty) that is the subject of this paper. In addition, more recent competitive grant efforts have added alternative fuel school buses and heavy-duty municipal vehicles to the DOE heavy-duty program.

Since AMFA was passed in 1988, however, several regulations and pieces of legislation have been passed which will also magnify the impact of the Federal government's alternative fuel truck and truck engine program. These include the Clean Air Act Amendments of 1990 (CAAA), the California Air Resources Board's (CARB's) emissions regulations, and the Energy Policy Act of 1992 (EPAAct). First, the CAAA set more stringent emission standards for heavy-duty truck engines, which alternative fuels may help to meet (through potentially lower emissions). This is especially true in the area of particulates, where the standard was reduced from 0.6 grams/brake horsepower-hour (g/bhp-hr) in 1990 to 0.1 starting in 1994. NO<sub>x</sub> levels must also be reduced in order to meet a standard of 4.0 g/bhp-hr starting in 1998 (versus the 1990 level of 6.0 and 1991 level of 5.0). In addition, the CAAA also set requirements for "clean fuel" fleets, consisting of mandates for the use of cleaner fuels for both heavy-duty vehicle (HDV) and LDV fleets in the worst air quality regions starting in 1998. These cleaner fuels include both alternative (non-petroleum) fuels and reformulated gasoline and low-sulfur diesel fuels. Second, CARB's establishment of stricter emissions performance levels for both HDVs and LDVs also points to increased contributions (toward meeting levels) by alternative fuels.

CARB's standards also call for emission level reductions for heavy-duty truck engines similar to those in the CAAA.

The third major package passed was EPO. Its purpose was to improve national energy security through increased use of alternative fuels and improved efficiency. EPO initiated an attempt to address the market barriers to AFV use through incentives (such as tax deductions for vehicles and refueling stations) and AFV fleet mandates for Federal, state, alternative fuel provider, and local government and private fleet operators. EPO also repealed the termination date of AMFA, originally set for September 30, 1997. It is believed that this repeal was done to allow AMFA to serve as a model (or almost an implementing regulation) for future AFV acquisitions by the Federal government. In fact, EPO called for increased data collection efforts based upon the AMFA activities, expanding the subject vehicles from "AMFA vehicles" to a "representative sample of the Federal fleet."

## **The DOE Program**

### **Objectives**

The Alternative Fuel Heavy-Duty Vehicle Program has four principal objectives. The first is to generate data on all significant alternative fuels, primarily methanol, ethanol, and natural gas, in a comprehensive test and evaluation program. The second is to conduct a geographically broad-based demonstration program with test sites throughout the country. The third is to involve as many user sectors and industry members as possible. Fourth, and finally, the program aims to generate data on alternatively fueled HDVs and heavy-duty engines and make this information available to users, potential users, and hardware manufacturers through the Alternative Fuels Data Center (AFDC). Access to the AFDC can be obtained by contacting the National Alternative Fuels Hotline at 1-800-423-1DOE.

### **Structure**

The DOE heavy-duty program includes both DOE-funded and non-DOE-funded alternative fuel truck demonstrations, as well as the alternative fuel state/municipal heavy-duty vehicle program. Under the DOE-funded truck programs, funds are supplied in two ways. First, some fleet operations are cost-shared by DOE. Other fleets, however, only receive funds for the incremental costs of the AFVs. In the non-DOE-funded programs, DOE is simply receiving data from some programs, while supporting other data collection efforts under a number of different types of agreements. The school bus/heavy-duty vehicle program also includes three school districts receiving DOE funding, as well as a number of other school systems, municipalities, and states operating under joint state/DOE grants. Under the grants, DOE is providing funding for a portion of the programs' costs to encourage utilization of vehicles from original equipment manufacturers (OEMs). Funds for the vehicles are being provided under a variety of cost-sharing and cost-matching arrangements. Converted vehicles are ineligible for the grant program, in line with the objective of encouraging manufacture of AFVs under these programs.

## Participants

### *Hardware Suppliers*

Consistent with the program goal of involving the heavy-duty engine/vehicle industry to the maximum practical extent (as well as covering as much of the country and as many fuels as possible), engines built by many of the major U.S. heavy-duty manufacturers are represented in DOE-supported fleets, including those from:

- Detroit Diesel Corporation (DDC)
- Cummins
- Caterpillar
- Tecogen
- Hercules
- Navistar
- Mack

The following engine and fleet operator summaries are based on discussions with personnel at the concerns named.

Detroit Diesel Corporation (DDC), in its alternative fuels work, is placing primary emphasis on the development and certification of spark ignition natural gas engines. Its Series 30G medium-duty engine, developed in a joint venture with Navistar, is in production for highway applications. Pending finalization of an agreement with Navistar, DDC will develop and market the Series 40G, based on Navistar's 8.7 liter in-line six-cylinder diesel. DDC expects to obtain medium-duty engines in the 250 to 300 horsepower range from this program. The Series 50G, an 8.5 liter heavy-duty engine, is in production for transit bus applications and is being developed for trucks. A 50G model calibrated for liquefied petroleum gas (LPG) is also being developed. DDC's largest natural gas engine, the 12.7 liter Series 60G, is under development for truck applications from 300 to 400 horsepower.

DDC views CNG, LNG and LPG as the lowest-cost alternative fuels currently available. The current high prices of alcohols are at least partly responsible for diminished customer interest in alcohol-fueled heavy-duty engines. DDC has no current orders for its 6V-92TA methanol and ethanol engines, although there are approximately 550 of these in service.

All of DDC's natural gas-fueled engines, medium- and heavy-duty, share key technological features; among the most important is a large and increasing degree of electronic control. Currently, the company's DDEC (Detroit Diesel Electronic Control) manages fuel metering, spark scheduling and throttle control. Other common gas engine characteristics are lean combustion, 10:1 compression ratio and wastegate-controlled turbocharging with air-to-air charge cooling. In the future, DDC believes, the technology may become available to sense exhaust gas hydrocarbon level and fuel composition. Sensors based on these technologies could be used to provide improved engine control and engine protection from the effects of low-octane gaseous fuels. DDC foresees the need to protect gaseous-fueled heavy-duty engines from damage in virtually all situations since the thermal stress they experience is greater than for comparable diesels. Moreover, natural gas composition is typically more variable than that of diesel fuel.

Cummins Engine Company currently produces or is developing four medium- and heavy-duty natural gas engines. Natural gas-fueled derivatives of proven diesel platforms are the focus of the company's attention due to natural gas' availability, favorable cost and the potential of lean-burn, spark-ignition engines to produce very low emissions while operating at high efficiency. Cummins' B5.9G engine has demonstrated ULEV emissions capability and over 100 have been built. The 195-horsepower version is in production. A 150-horsepower version will become available late in 1995 and future ratings are planned. The C8.3G engine is undergoing performance and mechanical development testing. Approximately 10 engines have accumulated over 7,000 hours of test experience and this heavy-duty, lightweight engine is expected to enter into field testing in trucks and buses soon. Production is planned to begin early in 1996. The L10G engine, introduced at a 240 horsepower rating in 1991, was uprated to 260 HP in 1994. Equipped with an oxidation exhaust catalyst, the L10G meets the California Air Resources Board's ULEV requirements. A 300 HP-rated model is scheduled for a January 1996 introduction. Over 750 L10G units have been produced, of which over 650 are in revenue service in more than 45 U.S. and Canadian fleets. The M11G, to be introduced early in 1998, will continue the current trend of Cummins' design philosophy, and feature full electronic engine management including closed-loop fuel control and enhanced built-in diagnostics.

Caterpillar Engine Division has done less work with spark-ignition natural gas engines than other heavy-duty engine manufacturers since Caterpillar does not market heavily to the city bus sector. Nonetheless, the company has developed two diesel-derivative SI gas engines, the 10-liter G3306 and the G3406, a 14-liter power plant. The first operates at the stoichiometric air-fuel ratio and is equipped with a three-way exhaust catalyst. The 350-horsepower G3406 is a lean-burn engine that uses an oxidation catalyst. The 250-horsepower 3306 is also available in an LPG-calibrated version rated at 235 horsepower. Both engines are fitted with digital electronic ignition control and are turbocharged and air-to-air aftercooled. The G3406 also has electronic detonation protection.

Caterpillar is investigating the concept of a direct-injection (DI), glow plug-ignition natural gas engine. Preliminary work suggests that such an engine could be capable of efficiencies in the range of 45 percent. Nitrogen oxides emissions are expected to be lower than those of a comparable diesel engine, but higher than those of a lean-burn, spark-ignition natural gas engine.

Caterpillar is also working on a diesel-cycle flexible-fuel engine that could use variable blends of diesel fuel and methanol. A fuel sensor signal is used to make adjustments of injection timing and volume based on the relative proportions of the fuel blend components.

In a joint venture with A-55 Limited Partnership, Caterpillar has formed Advanced Fuels LLC. The new company will seek to develop and commercialize a water-diesel fuel emulsion that has shown promise of significant NO<sub>x</sub> reductions from diesel engines.

Tecogen (Division of Thermo Power Corporation) continues to develop natural gas engines based on General Motors gasoline-fueled power plants. An additional 276 TecoDrive® CNG-fueled, 4.3-liter engines will be produced for United Parcel Service by Thermo Power's Crusader Engine division. These will retain the stock 8.3 compression ratio (CR) in contrast to the 12.2 CR of the 20 engines delivered to UPS last year. Engines in this second build will operate at the stoichiometric air-fuel ratio and use a 3-way exhaust catalyst designed for GM large-block gasoline-fueled engines. Economic considerations strongly influenced the decision to stay with the stock compression ratio

and to use a catalyst not optimized for natural gas exhaust. In engine orders of dozens or hundreds, rather than thousands or tens of thousands, the cost of extensive engine modification (and loss of the original equipment manufacturer's warranty) can be prohibitive and unit part costs also tend to be high. Tecogen is pursuing ULEV certification for this heavy-duty engine. There is also interest in developing natural gas fuel systems for other GM engines such as the 5.7 liter V-8 and for the big-block V-8s. Tecogen would use the Holley gas injector system for these packages that is the basis for the 4.3 liter fuel delivery system. Tecogen is completing development of a diesel-to-natural gas conversion package for the Navistar DT 466. Sponsors of this program include DOE (through NREL), Southern California Gas and GRI. Tecogen's approach will be to lower the effective compression by limiting the intake valve duration while retaining the expansion ratio of the diesel.

Hercules Engine Company is currently working with only one alternative fuel -- natural gas. They produce two natural gas engines, both of which are four-stroke cycle spark-ignition engines with turbocharging and aftercooling. There are only about a dozen of the four-cylinder GTA 3.7s in the field so far. However, the U.S. Postal Service is evaluating 54 two-ton step vans equipped with the 3.7 liter engine and may expand its fleet significantly if test results are positive. This development program has been supported by DOE. The GTA 5.6 is represented by over 400 units now in revenue service. Hercules rates the latter engine for chassis up to 30,000 pounds gross vehicle weight. While this market consists primarily of school and transit buses, the engine has also been installed in some specialty vehicles, such as some of the street sweepers operated by the New York Department of Sanitation. Both of Hercules' natural gas engines use the GFI fuel system. Hercules is working with GFI and with West Virginia University to develop a closed-loop fuel control for its engines. Introduction is expected to occur in late 1995. Hercules' engines have met CARB emission standards through 1998 without exhaust gas aftertreatment. Hercules considers that an important capability of its electronic feedback fuel metering system is compensating for variation of natural gas composition and thus keeping engine emissions within regulated limits.

Navistar International continues to emphasize natural gas in its alternative fuel engine development work. The 7.3 liter natural gas engine that Navistar developed jointly with Detroit Diesel Corporation will be marketed this year (by both companies). A second such joint development project is under consideration. This would involve Navistar's 8.7 liter, in-line six-cylinder engine.

Demonstration of the 7.3 liter engine in buses began in the spring of 1994. These engines performed well, but represented a significantly less advanced technology than the current 7.3 liter engine, which uses electronic rather than mechanical fuel management and a natural gas-optimized exhaust catalyst. Occasional difficulties were encountered in California as a result of high ethane and propane levels in the fuel. The relatively lower levels of methane in this gas led to lower octane ratings which caused detonation and power loss in the demonstration engines.

Navistar's sole methanol-fueled demonstration engine (Model DT 466) had been removed from a road sanding truck in South Lake Tahoe, California, where it had served for almost two years, and installed in a truck in the Sacramento County fleet in an effort to increase the engine's operating hours. Piston erosion observed last summer proved to be the result of glow plug failure and was not fuel-related. However, the DT 466 engine has evolved considerably since 1991, when the methanol engine was placed in service. Since replacement pistons are no longer available for the older version, the operators decided to terminate the project. The engine was removed from service late in 1994.

Mack Trucks, Inc. is developing spark-ignition natural gas engines based on its in-line six-cylinder E7 diesel. The E7, in ratings from 250 to 454 horsepower, is currently available with either mechanical or electronic fuel metering; the latter is expected to predominate in coming years. Mack's gas engines will be available in two versions. The first is rated 325 horsepower at 1950 RPM. It will be marketed primarily for solid waste handling vehicles with automatic transmissions. The second will be rated at 350 horsepower at 1800 RPM for over-the-road trucks. The engines are turbocharged and aftercooled with 11.5:1 compression ratios. Mack uses the MESA gas metering system.

Starting in the first quarter of 1996, two fleet demonstrations of trucks powered by the E7 engine will begin under DOE/ATA joint sponsorship. The first will involve seven LNG-fueled refuse packer trucks and seven diesel control trucks operated by Chambers Development Company in Washington, Pennsylvania. The second will involve two Mack-powered line-haul tractors fueled by a biodiesel blend and a single (petroleum) diesel control truck, as well as two other manufacturers' biodiesel and control trucks.

#### *User-Liaison Organizations*

A second important goal of the DOE heavy-duty alternative fuel engine/vehicle program is to provide a bridge to the vehicle users -- the heavy-duty vehicle fleet operators. Accordingly, DOE has contracted with other organizations which represent fleet owners, are themselves fleet owners, or which can make the information and lessons of the program available to the nation's fleet operators.

The American Trucking Associations Foundation's Trucking Research Institute (TRI) is collecting and making available to DOE data on current and past alternative fuel truck programs. The American Trucking Associations, Inc. (ATA) has established numerous alternative fuel demonstration programs. Commercial fleet owners are operating over 175 vehicles in eight states and keeping DOE apprised of these activities through the TRI. Operational data on 36 heavy-duty vehicles in five private, state and local government fleets are reported by the Trucking Research Institute. The California Energy Commission (CEC) has begun providing DOE with data developed from heavy-duty CNG-fueled trucks in California. DOE provided some funding for these vehicles.

The Midwest Research Institute (MwRI), which operates the National Renewable Energy Laboratory (NREL) for DOE, issued subcontracts under the heavy-duty engine/vehicle program. NREL is providing funds to program participants and is acting, through the Alternative Fuels Data Center, as a clearinghouse for the information collected in the program.

Operating as part of DOE's information dissemination effort, the National Alternative Fuels Hotline provides public access to alternative fuel information and reports. The National Alternative Fuels Hotline has been available as a resource to the public since June 1992. Since its inception, it has received more than 13,000 calls. Callers are typically interested in evaluating alternative fuels as possible replacements for petroleum transportation fuels as well as impending Federal and state legislative and regulatory issues.

The alternative fuel activities of the Illinois Department of Energy and Natural Resources are continuing under the state's Department of Commerce and Community Affairs. Corn-based ethanol is the subject of all these programs, which include heavy- and light-duty vehicles and ethanol production. Among the heavy-duty vehicle demonstration projects is the Archer-Daniels-Midland line-haul tractor fleet. These four White-GMC ethanol-fueled trucks and one White-GMC diesel control tractor are powered by DDC 6V-92TA engines. The four E-95-fueled trucks had accumulated an aggregate of about a million miles by June of 1995. One had shown signs of excessive bearing wear. Disassembly of the engine confirmed this and the bearings and cylinder liners were replaced. The electronic control units of all four engines were reprogrammed to reduce cylinder pressures by 250 to 300 psi. Detroit Diesel Corporation engineers believe the alcohol engines' 23:1 compression ratio, in combination with advanced injection timing, caused overly high cylinder pressures. The National Renewable Energy Laboratory is supporting this project with approximately \$368,000.

The New York Department of Sanitation (NYDOS) expanded its fleet of natural gas-fueled refuse collection trucks to 17 with the purchase of 10 new trucks. These additional vehicles were purchased without funding support from DOE. Impressed with the performance of its existing CNG vehicles, NYDOS elected to enlarge its fleet using city funds. The 17 collection trucks encompass engine technology from three major manufacturers. There are five Caterpillar 3306 engines, seven Cummins L-10s (including a prototype in service since 1989), and five DDC Series 50Gs. NYDOS' sole alcohol-fueled vehicle, a DDC 6L-71 methanol trash collection truck, completed its testing period and was retrofitted with a conventional diesel engine. Brooklyn Union Gas operates the CNG fueling station used by NYDOS. The station operator records the vehicle odometer reading at the time of refueling and fuel input is recorded automatically. These data are downloaded and sent to the AFDC.

Customarily, senior NYDOS drivers are given first choice of vehicles. In the past, their usual response has been to choose the newest equipment. However, senior drivers have been observed to bypass the newest trucks in order to retain the natural gas vehicles. Two reasons have been identified. First, the natural gas trucks are approximately 10dB quieter than their Diesel counterparts. Second, the workers (especially the members of the work crews who walk behind the vehicles) appreciate the clean, low-odor exhaust.

The recently completed South Coast Alternative Fuels Demonstration (called CleanFleet) was a multi-sponsor test and demonstration program involving 109 Federal Express Corporation package delivery vans. DOE provided approximately one third of the \$6.6 million project budget, not including an additional \$4.2 million of in-kind services contributed by vehicle and fuel manufacturers, Federal Express and the California Air Resources Board.

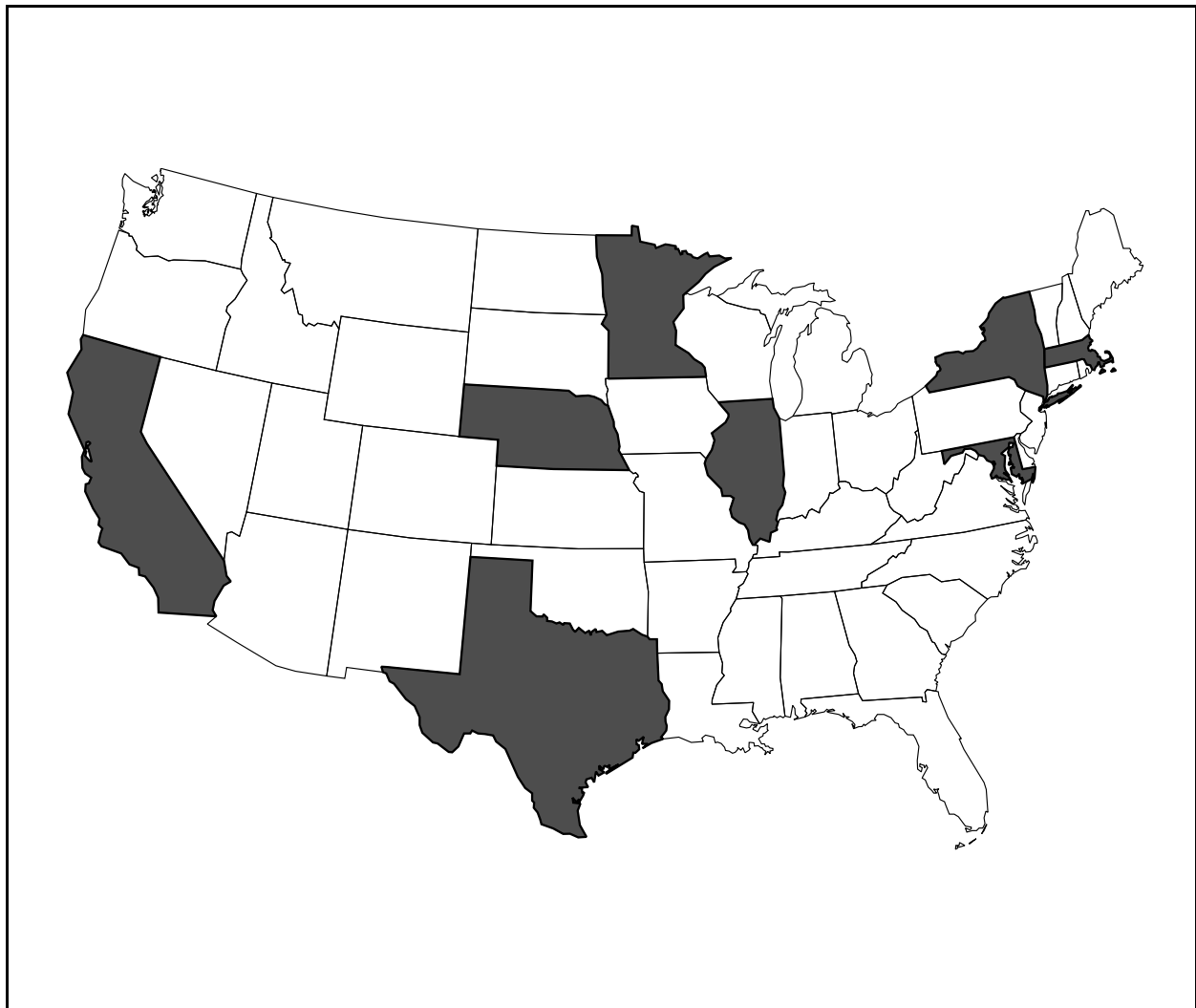
The CleanFleet project's medium-duty trucks were divided into six groups to operate on four alternative fuels and on conventional (unleaded regular) gasoline. Vehicles were phased into the program from April to November 1992. Battelle (Columbus) provided project monitoring and oversight and will issue a final report in November 1995.

## Program and Technology Status

### DOE-Funded Alternative Fuel Truck Program

Currently within DOE's truck application program, there are a number of diverse efforts taking place. Participating fleets receiving DOE funding are located throughout the country, as shown in Figure 1. There are 177 trucks included in the program, ranging from medium-duty delivery trucks up to tractor-trailer combinations. As previously indicated, the engines used in these vehicles cover a wide range of potential applications, and include representation from most of the major U.S. manufacturers. A complete list of the current program participants is provided in Table 1. Nearly all of the vehicles listed are currently in operation; some have recently completed their data collection efforts and others will go into operation in the near future.

**Figure 1: Map of Participants in the DOE-Funded Alternative Fuel Truck Projects**



**Table 1. DOE-Funded (American Trucking Association)  
Alternative Fuel Commercial Truck Demonstration Projects**

<b>Operator</b>	<b>Location</b>	<b>Number</b>	<b>Fuel (Engine)</b>	<b>Status</b>
United Parcel Service	New York	10	CNG (Ford)	Ongoing
United Parcel Service	Texas	15	CNG (GM)	Ongoing
United Parcel Service	Maryland	20	CNG (Tecogen)	Ongoing
U.S. Postal Service	CA,MA,MD,NY	8	CNG (Tecogen)	Ongoing
Archer-Daniels-Midland	Illinois	4	Ethanol (DDC)	Ongoing
NY Dept. of Sanitation	New York	6	CNG (Cummins)	Ongoing
Hennepin County	Minnesota	2	Ethanol (DDC)	Ongoing
Nebraska Dept. of Roads	Nebraska	2	Ethanol (DDC)	Ongoing
Ag Processing	Iowa	6	Biodiesel 35 (Mack, Cummins, DDC)	Ongoing
Liquid Carbonic	Texas	3	LNG (DDC)	Ongoing
Los Angeles Times	California	1	CNG (DDC)	Ongoing
Detroit Diesel Corp.	Michigan	1	LNG (DDC)	Ongoing
Chambers Development Co.	Pennsylvania	7	LNG (Mack)	Ongoing
Liquid Carbonic	Texas, Louisiana	2	LNG (DDC)	In Service
Detroit Diesel	Michigan	2	LNG (DDC)	In Service
Wal-Mart	California	2	LNG (DDC)	In Service
UNOCAL	California	1	LNG (DDC)	In Service
Con-Way	California	2	LNG (Cummins)	Planned
Vons Companies, Inc.	California	1	CNG (Caterpillar)	Completed
SCAQMD - Federal Express	California	7	CNG (GM)	Completed
SCAQMD - Federal Express	California	7	CNG (Chrysler)	Completed
SCAQMD - Federal Express	California	7	CNG (Ford)	Completed
SCAQMD - Federal Express	California	20	M-85/Gasoline (Ford)	Completed
SCAQMD - Federal Express	California	13	LPG (Ford)	Completed
SCAQMD - Federal Express	California	7	LPG (GM)	Completed
SCAQMD - Federal Express	California	7	RFG (Chrysler)	Completed
SCAQMD - Federal Express	California	7	RFG (Ford)	Completed
SCAQMD - Federal Express	California	7	RFG (GM)	Completed
<b>TOTAL</b>		177		

## Heavy-Duty State/Municipal Vehicle Alternative Fuel Demonstration Program

As with the DOE-funded Alternative Fuel Truck Programs, the Heavy-Duty State/Municipal Vehicle Alternative Fuel Demonstration Program involves participation of organizations throughout the country, as shown in Figure 2. Over 170 buses are participating in the grant program. The earliest school buses (Phase 0) began operation at the end of 1991 in Tulsa, Oklahoma. The first round of DOE/state competitive grants were awarded during the summer of 1992, so most of these programs are underway. Some of the Phase 1 participants have been granted one-year extensions because OEM buses were not available to meet their requirements. A second round of awards (with the scope expanded to all heavy-duty state and municipal AFVs) was announced in mid-August 1993. This Phase 2 part of the program includes CNG, LPG, ethanol and soydiesel vehicles. Vehicle types include school buses, refuse haulers, street sweepers, dump trucks and other utility vehicles. In August of 1994, Phase 3 grants were announced. Details of Phase 0 through Phase 3 are shown in Tables 2A, 2B, and 2C.

Most buses are CNG-powered with a variety of bus/engine manufacturers providing the vehicles. Bus manufacturers include Thomas, Carpenter, and Bluebird. CNG-powered bus engine manufacturers participating include Hercules, Tecogen, Caterpillar, DDC, and Navistar. Of the vehicles currently in the program, only two buses are methanol-fueled (both in Pennsylvania). The first methanol bus was delivered in May 1994 as part of the Phase 1 grant program. The bus was manufactured by Carpenter and is powered by a DDC 6V-92TA engine. The second bus will be delivered in the near future as part of the Phase 3 grant. Four soydiesel school buses with Cummins powerplants were added to the data collection fleet with Phase 2 grant money. The first soydiesel bus was delivered in January 1994 and the last bus was delivered in May 1994.

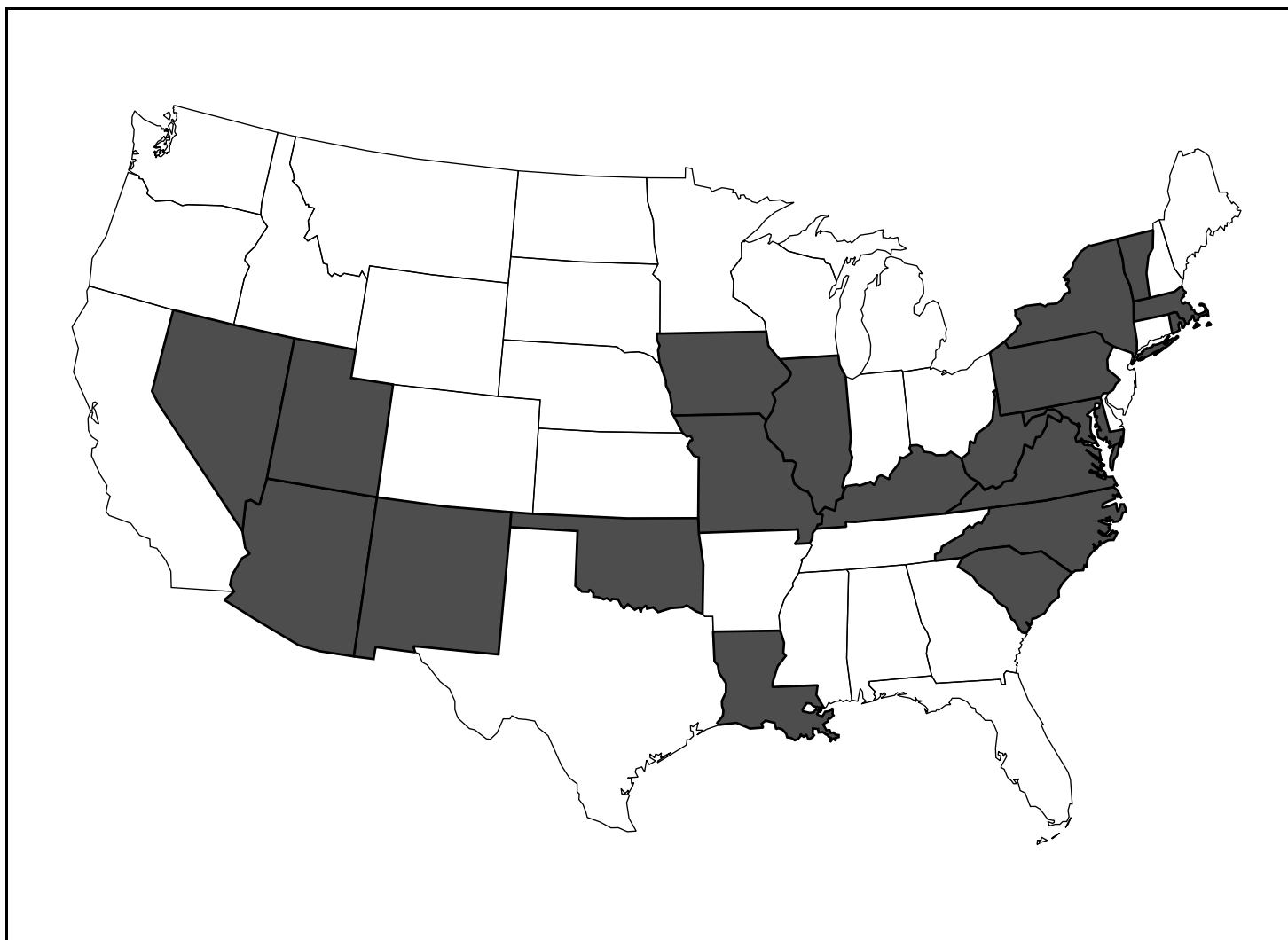
In addition, over 70 heavy-duty state and municipal vehicles are participating in the DOE-funded program. Fuels include CNG, ethanol, LPG, and soydiesel. Vehicles will include street sweepers, dump trucks, wreckers, over-the-road tractors, airport shuttles, vans, and jet vac machines.

The heavy-duty truck portion of the program started with the Phase 2 grants in 1993 and continued with the Phase 3 grants in 1994. For Phase 3, 40 of the 42 vehicles participating will be heavy-duty trucks. Once again, the majority of the heavy-duty trucks participating in the program are CNG powered. Many of the grant recipients have not yet chosen an engine manufacturer to power their vehicles.

## Non-DOE-funded Alternative Fuel Commercial Truck Data Collection Program

In addition to the projects to which DOE supplies funding, several commercial fleet operators are operating alternative-fueled heavy-duty vehicles as demonstration fleets. These companies are working with DOE and supplying data from 48 alternative-fueled heavy-duty vehicles to the National Renewable Energy Laboratory's Alternative Fuels Data Center in Golden, Colorado via the American Trucking Association. The national distribution of these fleets is shown in Figure 3 and the projects are outlined in Table 3.

**Figure 2: Map of Heavy-Duty State/Municipal Vehicle Alternative Fuel Demonstration Program**



**Table 2A: Heavy-Duty State/Municipal Vehicle Alternative Fuel Demonstration Program  
Phase 0 and 1 School Bus Grants**

Phase	Operating Jurisdiction	State	Number	Fuel (Engine <sup>(a)</sup> )	Vehicle Type
0	Tulsa County	Oklahoma	55	CNG	School Buses
0	Tulsa County	Oklahoma	45	CNG	School Buses <sup>(b)</sup>
0	Town of Weston	Massachusetts	3	CNG	School Buses
0	Town of Weston	Massachusetts	2	CNG	School Buses <sup>(b)</sup>
0	Wood County	West Virginia	2	CNG	School Buses
0	Wood County	West Virginia	2	CNG	School Buses
0	Wood County	West Virginia	4	CNG	School Buses <sup>(b)</sup>
1	Maricopa County	Arizona	4	CNG	School Buses
1	Braxton County	West Virginia	3	CNG	School Buses
1	Montgomery County	Pennsylvania	1	Methanol (DDC)	School Bus
1	D.C. Public Schools	District of Columbia	4	CNG (Hercules)	School Buses
1	Springfield School District	Missouri	4	CNG (Hercules)	School Buses
1	Jordan School Dist.	Utah	4	CNG (Tecogen)	School Buses
1	University of Vermont	Vermont	2	CNG	School Buses
1	Shenendehowa School District	New York	2	CNG (Hercules)	School Buses
1	Marcus Whitman School District	New York	2	CNG	School Buses
1	Albuquerque	New Mexico	4	CNG	School Buses
1	Franklin County	Kentucky	4	CNG (DDC)	School Buses
1	Montgomery County	Maryland	3 <sup>(c)</sup>	CNG	School Buses
1	Baltimore County	Maryland	3 <sup>(c)</sup>	CNG	School Buses
	<b>TOTAL</b>		152		

(a) The names of original equipment engine manufacturers are provided where this information could be obtained.

(b) Converted vehicles (all others are OEM vehicles)

(b) Two of the vehicles were purchased with DOE funding, one was purchased with Maryland state funds.

**Table 2B: Heavy-Duty State/Municipal Vehicle Alternative Fuel Demonstration Program  
Phase 2 School Bus and Heavy-duty Vehicle Grants**

Phase	Operating Jurisdiction	State	Number	Fuel (Engine Mfr. <sup>(a)</sup> )	Vehicle Type
2	Peoria	Illinois <sup>(b)</sup>	2	E95	Snow Plow/Construction Trucks
2	Peoria	Illinois <sup>(b)</sup>	1	E95	School Bus
2	Louisville/ Jefferson County	Kentucky	3	CNG (Ford)	Municipal Wreckers
2	Mecklenburg County	North Carolina	4	CNG (Hercules)	School Buses
2	State of Nevada	Nevada	2	CNG	15,000 GVW Crew Cab Dump Trucks
2	State of Nevada	Nevada	2	CNG	Tymco Street Sweepers
2	New York City	New York	2	CNG (Hercules)	Athey Street Sweepers
2	Bethlehem School District, Albany County	New York	2	CNG (Hercules)	Transit Style Buses used in school bus operation
2	East Providence	Rhode Island	4	CNG (Tecogen)	School Buses
2	Richland and Lexington Counties	South Carolina	4	CNG	Heavy Duty Trucks
2	Richmond, Northern Virginia, and Suffolk	Virginia	3	LPG	Class 7 (28,000-33,000 GVW) Dump Trucks
2	Virginia Beach	Virginia	1	CNG (Navistar)	School Bus
2	Pleasants County	West Virginia	2	CNG	Transit Style Buses used in school bus operation
2	Washington, DC	District of Columbia	3	CNG	Jet Vac Machines
2	Washington, DC	District of Columbia	1	CNG	38,000 GVW Dump Truck
2	Waco and Washington Community School Districts	Iowa	4	Soydiesel <sup>(c)</sup> (Cummins)	School Buses
	<b>TOTAL</b>		40		

(a) The names of original equipment engine manufacturers are provided where this information could be obtained.

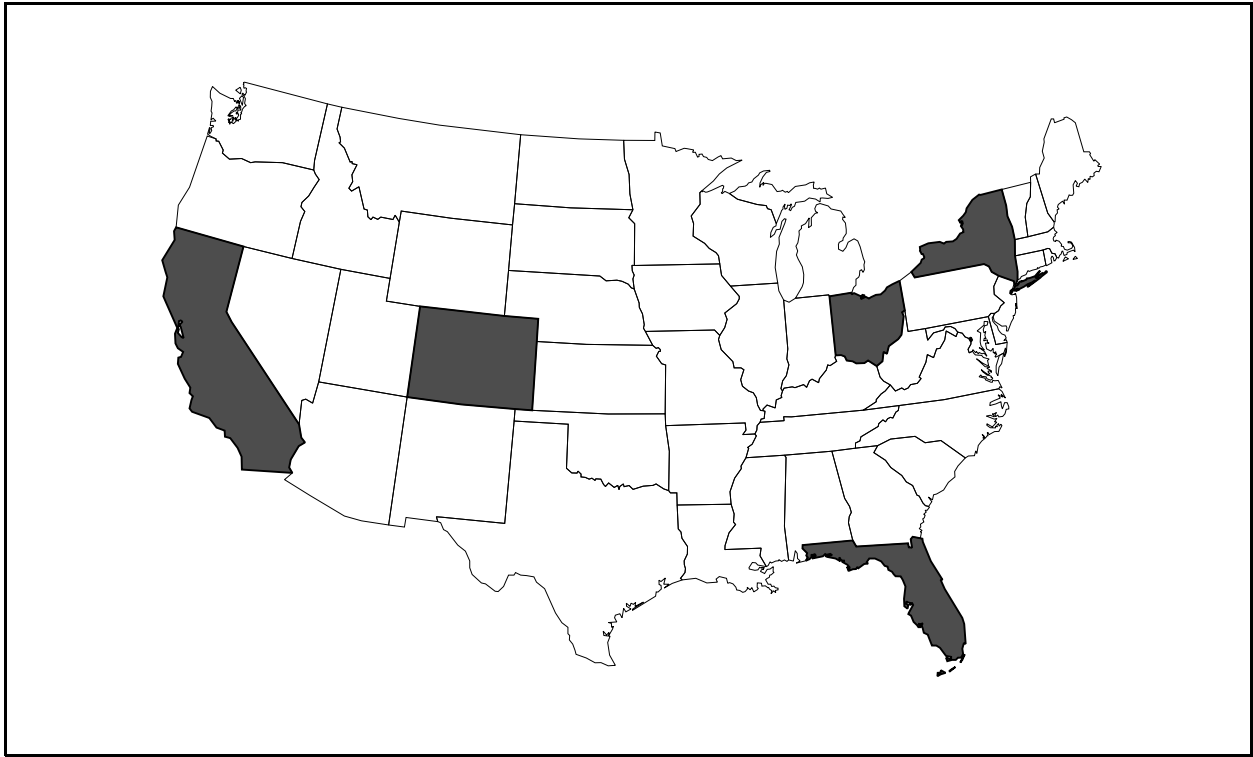
(b) This project is likely to be cancelled.

(c) 70% Soydiesel / 30% Diesel blend

**Table 2C: Heavy-Duty State/Municipal Vehicle Alternative Fuel Demonstration Program  
Phase 3 School Bus and Heavy-duty Vehicle Grants**

Phase	Operating Jurisdiction	State	Number	Fuel	Vehicle Type
3	Washington, DC	District of Columbia	4	CNG	Ford E350s
3	Boston	Massachusetts	4	CNG	Airport Shuttles
3	Long Beach	California	4	CNG	Refuse Haulers
3	State of MD	Maryland	7	CNG	Heavy-duty Vehicles
3	Kenosha	Wisconsin	3	CNG	Refuse Haulers
3	Kenosha	Wisconsin	1	CNG	Street Sweeper
3	Chicago	Illinois	7	Diesel, LPG, Ethanol, CNG	Refuse Haulers
3	Las Vegas	Nevada	2	CNG	Street Sweepers
3	Phoenix	Arizona	2	CNG	Tractor Trailers
3	Phoenix	Arizona	2	CNG	Dump Trucks
3	Phoenix	Arizona	2	CNG	Refuse Haulers
3	State of PA	Pennsylvania	1	M100	School Bus
3	State of PA	Pennsylvania	1	CNG	School Bus
3	Austin	Texas	2	LPG	Refuse Haulers
	<b>TOTAL</b>		42		

**Figure 3: Map of Participants in the Non-DOE-Funded Alternative Fuel Commercial Truck Data Collection Program**



**Table 3. Non-DOE-Funded (American Trucking Association) Alternative Fuel Commercial Truck Data Collection Projects**

<b>Operator</b>	<b>Location</b>	<b>Number</b>	<b>Fuel (Engine Mfgr.)</b>	<b>Status</b>
Transportation Mgmt. Systems	Colorado	1	CNG (Cummins)	Completed
City of Tonawanda	New York	1	CNG (Hercules)	Ongoing
Entenmann's Bakery	Florida	5	CNG (Hercules)	Ongoing
Coors Brewing Company	Colorado	1	Ethanol (DDC)	Completed
Roadway Services	Ohio	10	LNG (Tecogen/Cummins)	Ongoing
Golden State Foods	California	1	Methanol (DDC)	Completed
Federal Express	California	1	Methanol (DDC)	Completed
<b>TOTAL</b>		20		

## Data Collection

Both ongoing and recently completed data collection activities will be discussed in this section. Two fleets recently completed their data collection activities, the Vons Companies, Inc. and Federal Express. A final report has been issued for the Vons Companies data collection project entitled "Alternative-Fueled Truck Demonstration Natural Gas Program: Caterpillar G3406LE Development and Demonstration." This report (NREL/TP-425-6969) was published by the National Renewable Energy Laboratory in June 1995 and can be obtained from the National Alternative Fuels Hotline (1-800-432-1DOE). The Federal Express fleet recently concluded data collection activities and a final report is due in November 1995. However, preliminary data are available and will be reported in this paper.

Fleets of heavy-duty and medium-duty vehicles now participating in the DOE-supported data collection effort include the New York Department of Sanitation, Archer-Daniels-Midland, Hennepin County (Minnesota), the United States Postal Service, the Nebraska Highway Department, Ag Processing and Liquid Carbonic. Also, DOE supports the American Trucking Association efforts in the collection of data from many sites engaged in heavy-duty alternative fuel activities. Altogether, more than 200 vehicles are participating or have participated in the data collection program. These vehicles are in addition to the DOE-supported heavy-duty vehicle/school bus program.

For the ongoing data collection fleet, data exist in limited quantities because of the projects' active status. Some difficulties still remain with collecting data from the present fleet. For example, the United States Postal Service vehicle operators are unable to report the fuel usage because no fuel metering system is attached to the natural gas compressors used for refueling. This precludes the calculation of vehicle fuel economy.

### Fuel Economy

Both completed and ongoing project data are available and will be presented in the fuel economy section. However, the data from ongoing data collection activities must be statistically validated. It will be made publicly available at the conclusion of the program. At this time only the Vons Companies data is available for release. Data presented here from both ongoing activities and the Federal Express fleet are preliminary. These preliminary data should not be regarded as an adequate basis for firm conclusions on the fuel economy of alternative-fueled heavy-duty vehicles and should only be used to suggest trends.

#### *Vons Companies, Inc. Data Collection Fleet Fuel Economy (final)*

Vons Companies, Inc. collected data for 14 months from one CNG line-haul truck and one diesel control line-haul truck. This project terminated data collection December 1993. More than 30,000 miles were accumulated on the CNG-powered line-haul truck. Energy economy data from the project are shown in Table 4.

**Table 4. Vons Companies, Inc.**  
**CNG and Diesel Control Fleet Fuel Economy.**  
*(Source: Acurex Environmental Corp.)*

CNG Line-haul Truck	Total Mileage Accumulated during Data Collection	Average Energy/Fuel Economy
Truck No. 9207	32,369	4.64 m/dge <sup>(1)</sup>
Truck No. 9200 Diesel Control	115,585	6.63 mpg <sup>(2)</sup>

(1) miles per diesel gallon equivalent (1 dge = 36.0 MJ)

(2) miles per gallon

The in-use fuel economy of the CNG line-haul truck was disappointingly low. Final data show that the CNG Truck No. 9207 had a 30% lower energy economy than the Diesel control truck (No. 9200). Several adjustments were made to improve the energy economy of the CNG truck but time did not permit the evaluation of their effect.

*Federal Express Data Collection Fleet Fuel Economy (preliminary)*

The Federal Express fleet has ended its demonstration period. Fuel economy data collection terminated on September 30, 1994. However, other aspects of the program are continuing, such as engine disassembly for wear evaluation. A final report on the entire project is expected to be completed by November 1995. Some preliminary data are available (including fuel economy) for the fleet. These data are shown in Table 5.

*Archer-Daniels-Midland Data Collection Fleet Fuel Economy (preliminary)*

For the Archer-Daniels-Midland fleet of four line-haul E95 trucks and one diesel control line-haul truck, the data appear to indicate that the E95 trucks have similar fuel economy on an energy equivalent basis as the diesel control truck. However, the diesel control vehicle energy economy is at the maximum range of the energy economy for the E95 vehicle fleet. These fuel economy numbers are based on data acquired from the National Renewable Energy Laboratory's Alternative Fuels Data Center in Golden, Colorado. The data appear in Table 6.

*New York Department of Sanitation Data Collection Fleet Fuel Economy (preliminary)*

The New York Department of Sanitation has collected data on the six CNG refuse haulers and one diesel control refuse hauler in its fleet. These data are shown in Table 7. It appears that the diesel control vehicle energy economy slightly exceeds the CNG fleet average. This may in fact be true, but these data are preliminary and no conclusions should be drawn.

**Table 5: Federal Express**  
**Data Collection Fleet Fuel Economy: The First 5,000 Miles (March 1993).**  
*(Source: Battelle)*

Fuel Type	Vehicle Manufacturer	Unadjusted	Adjusted <sup>(1)</sup>
CNG	Chevrolet	8.6 m/gge <sup>(2)</sup>	8.0 m/gge <sup>(2)</sup>
	Dodge	7.7 m/gge <sup>(2)</sup>	8.1 m/gge <sup>(2)</sup>
	Ford	10.3 m/gge <sup>(2)</sup>	9.3 m/gge <sup>(2)</sup>
Electric	G-Van	14.7 m/gge <sup>(2)</sup>	---
M-85	Ford	8.7 m/gge <sup>(2)</sup>	8.3 m/gge <sup>(2)</sup>
Propane	Chevrolet	8.3 m/gge <sup>(2)</sup>	7.3 m/gge <sup>(2)</sup>
	Ford	8.4 m/gge <sup>(2)</sup>	7.1 m/gge <sup>(2)</sup>
RFG	Chevrolet	7.3 m/gge <sup>(2)</sup>	7.7 m/gge <sup>(2)</sup>
	Dodge	8.0 m/gge <sup>(2)</sup>	8.4 m/gge <sup>(2)</sup>
	Ford	8.0 m/gge <sup>(2)</sup>	8.0 m/gge <sup>(2)</sup>
Unleaded	Chevrolet	9.0 m/gge <sup>(2)</sup>	8.6 m/gge <sup>(2)</sup>
	Dodge	9.0 m/gge <sup>(2)</sup>	8.2 m/gge <sup>(2)</sup>
	Ford	9.3 m/gge <sup>(2)</sup>	9.0 m/gge <sup>(2)</sup>

(1) Adjusted estimates based on a duty cycle of 40 miles per day with an average number of delivery stops.

(2) miles per gasoline gallon equivalent (1 gge = 30.8 MJ)

**Table 6. Archer-Daniels-Midland**  
**E95 and Diesel Control Fleet Fuel Economy.**  
*(Source: NREL)*

Ethanol (E95) Line Haul Truck	Truck Mileage (as of July 1994)	Average Energy/Fuel Economy
Truck No. 92002	223,219	5.76 m/dge <sup>(1)</sup>
Truck No. 92004	159,522	5.40 m/dge <sup>(1)</sup>
Truck No. 92006	192,032	5.18 m/dge <sup>(1)</sup>
Truck No. 92008	160,521	4.97 m/dge <sup>(1)</sup>
Weighted E95 Line Haul Truck Diesel Equivalent Average		5.33 m/dge <sup>(1)</sup>
Truck No. 92010 Diesel Control	245,686	5.76 mpg <sup>(2)</sup>

(1) miles per diesel gallon equivalent (1 dge = 36.0 MJ)

(2) miles per gallon

**Table 7. New York Department of Sanitation  
CNG and Diesel Control Fleet Fuel Economy.**  
(Source: NREL)

Truck No.	Truck Mileage (as of July 1994)	Average Energy/Fuel Economy
25CNG-001	5,244	1.41 m/dge <sup>(1)</sup>
25CNG-002	5,247	1.39 m/dge <sup>(1)</sup>
25CNG-003	7,511	1.43 m/dge <sup>(1)</sup>
25CNG-004	8,654	1.29 m/dge <sup>(1)</sup>
25CNG-005	3,124	1.46 m/dge <sup>(1)</sup>
25CNG-006	5,453	1.47 m/dge <sup>(1)</sup>
Weighted CNG Refuse Truck Diesel Equivalent Average		1.39 m/dge <sup>(1)</sup>
25AYX-603 Diesel Control	3,387	1.61 mpg <sup>(2)</sup>

<sup>(1)</sup> miles per diesel gallon equivalent (1 dge = 36.0 MJ)

<sup>(2)</sup> miles per gallon

*Hennepin County, Minnesota Data Collection Fleet Fuel Economy (preliminary)*

Hennepin County, Minnesota has collected data on two E95 snowplows and one diesel control snowplow in its fleet. As shown with the Archer-Daniels-Midland ethanol fleet, these data show that both types of vehicle have similar fuel economy on an energy equivalent basis, with the diesel control vehicle slightly exceeding the weighted average diesel equivalent fuel economy of the E95 vehicles. Again, caution must be exercised when assessing these data since they are preliminary. These data are shown in Table 8.

**Table 8. Hennepin County, Minnesota  
E95 and Diesel Control Fleet Fuel Economy.**  
(Source: NREL)

Ethanol (E95) Snow Plow Truck	Truck Mileage (as of July 1994)	Average Energy/Fuel Economy
Truck No. 3221	14,063	3.98 m/dge <sup>(a)</sup>
Truck No. 3228	8,348	3.68 m/dge <sup>(a)</sup>
Weighted E95 Snow Plow Truck Diesel Equivalent Average		3.89 m/dge <sup>(a)</sup>
Truck No. 3220 Diesel Control	21,789	4.37 mpg

<sup>(1)</sup> miles per diesel gallon equivalent (1 dge = 36.0 MJ)

<sup>(2)</sup> miles per gallon

## Emissions

Before emissions results are discussed, it should be noted that very limited emissions data are available at this time. Final emissions results are available for the CNG-powered Vons Companies line-haul truck. In addition, preliminary emissions data are available for the Federal Express CleanFleet vehicles. A full set of emissions test numbers should be collected before any conclusions are drawn. The early test results provide an indication of what might occur.

Available for testing the data collection vehicles are two Transportable Heavy-Duty Vehicle Emissions Testing Laboratories. These were developed under this program by West Virginia University. Use of these mobile laboratories permits evaluation of in-service emissions from alternative-fuel heavy-duty vehicles with a minimum of out-of-service time. They are scheduled to collect significant additional emissions data which should help provide a basis for firmer conclusions.

### *Vons Companies, Inc. Data Collection Fleet Emissions (final)*

The results of Vons' CNG-fueled line-haul Truck No. 9207 are shown in Table 9. These data show good repeatability of the hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>), and carbon dioxide (CO<sub>2</sub>) in successive iterations of the EPA Schedule (d) and FTA Commuter tests. Speciated HC analysis from one bag sample drawn during an EPA Schedule (d) test showed that approximately 90 percent of the total HC emissions were methane. It should be noted that both EPA and CARB consider methane to be nonreactive in photochemical ozone production.

Even though the HC emissions of the Vons CNG-powered line-haul truck are mostly methane, the mass of hydrocarbon emitted is still relatively high. Other CNG vehicles that have been fitted with natural gas catalysts show the potential for low total HC emissions. The catalyst installed on the Vons CNG-powered truck had a limited effect on the oxidation of methane.

### *Federal Express Data Collection Fleet Emissions (preliminary)*

In-use exhaust emissions results have been obtained from the first round of tests on CleanFleet vans. These results provide a detailed set of data on a variety of medium-duty vehicle technologies for model year 1992 alternative fuel vehicles. The data collected consist of regulated compounds, ozone precursors, air toxics, and greenhouse gases. The Federal Express fleet compared emission levels to those of the control gasoline portion of the test fleet. This was done to try to highlight the emissions benefits that can be obtained with alternative fuels. Figures 4A, 4B, and 4C show these comparisons.

As can be seen from the figures presented, emission improvements have occurred with most fuels. Once again, it should be noted that these vehicles are retrofitted gasoline vehicles with adjustments made to the exhaust aftertreatment. These vehicles and engines were not developed for use with these alternative fuels. Engines optimized for specific alternative fuels might improve the emission results presented here.

**Table 9. Vons Companies, Inc.  
CNG Line-haul Truck No. 9207 Emissions.**  
(Source: NREL)

Test Cycle	Inertia Weight (lb)	HC (g/mi)	CO (g/mi)	NOX (g/mi)	CO <sub>2</sub> (g/mi)	HCHO (g/mi)	PM (g/mi)	Fuel Economy (m/dge)
CBD	69,350	114.9	0.25	31.1	4,465	NM	0.0369	1.18
EPA	69,350	42.2	0.25	20.2	2,385	0.01	0.0665	2.25
EPA	69,350	40.3	0.28	20.0	2,347	0.01	0.0376	2.29
EPA	69,350	39.8	0.19	18.5	2,348	ND	0.0694	2.29
COM	69,350	12.9	0.12	17.2	1,764	0.02	0.0110	3.12
COM	69,350	17.2	0.07	16.6	1,767	0.01	0.0191	3.10
Idle <sup>(1)</sup>	69,350	27.7	0.71	2.4	1,058	NM	NM	NA
EPA	69,350	38.8	0.21	19.5	2,398	0.01	0.0654	2.24
COM	45,000	17.1	0.11	16.7	1,635	NM	0.0118	3.31

CBD = Federal Transit Administration's Central Business District cycle

EPA = U.S. Environmental Protection Agency Schedule (d)

COM = Federal Transit Administration's Commuter cycle

Idle = Idle cycle emissions prediction technique under development by Acurex Environmental

m/dge = miles per diesel gallon equivalent (1 dge = 36.0 MJ)

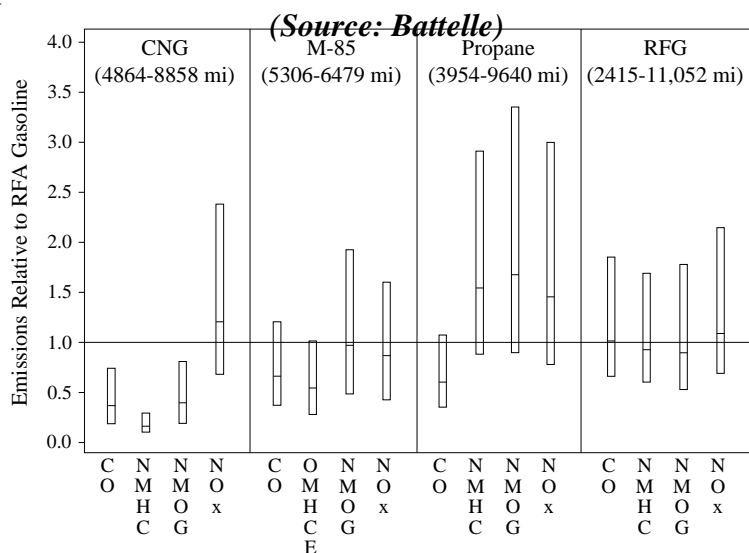
NM = Not measured

ND = Not detected

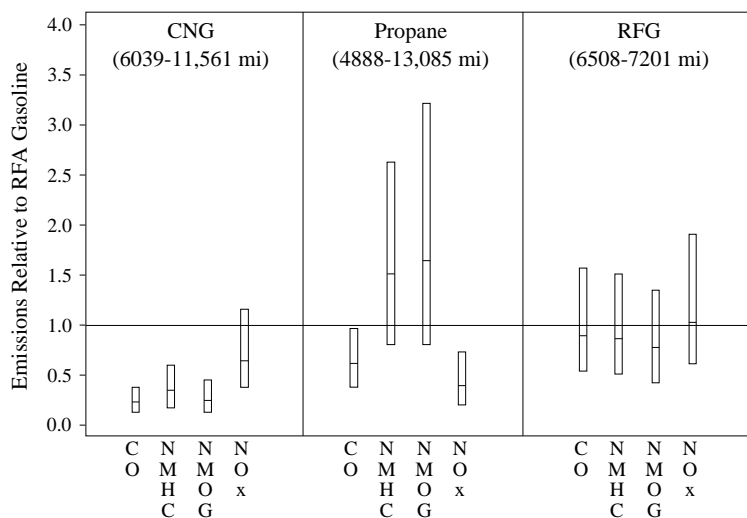
NA = Not applicable

<sup>(1)</sup> Emission results reported as total grams for test

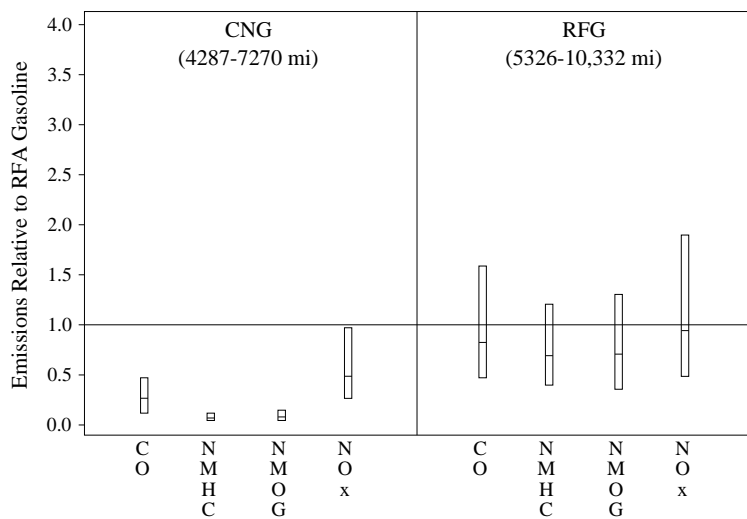
**Figure 4A: Federal Express Data Collection Fleet; Early Emission Levels of Regulated Compounds from Ford Vehicles Relative to Gasoline-Fueled Levels.**



**Figure 4B: Federal Express Data Collection Fleet; Early Emission Levels of Regulated Compounds from Chevrolet Vehicles Relative to Gasoline-Fueled Levels.**  
(Source: Battelle)



**Figure 4C: Federal Express Data Collection Fleet; Early Emission Levels of Regulated Compounds from Dodge Vehicles Relative to Gasoline-Fueled Levels.**  
(Source: Battelle)



## Emissions Standards

Currently, two sets of emissions standards exist for medium- and heavy-duty trucks in the United States, (1) U.S. Environmental Protection Agency (USEPA) standards as outlined by the Clean Air Act Amendments of 1990 (CAAA) and (2) California Air Resources Board (CARB) emissions standards. These two regulatory agencies have addressed their respective emissions standards to current problems encountered in their respective jurisdictions. The USEPA emissions standards are shown below in Tables 10 and 11. These standards are applicable to the weight classes identified and apply to the 49-state jurisdiction. An overview of these standards, current and future, has been included here to help establish a perspective on the regulatory environment in which DOE's alternative fuels heavy-duty engine/vehicle program is going forward, and in which manufacturers are operating.

California has different emission control needs than the other 49 states, which is reflected in CARB's emissions standards. However, by law California must meet or exceed the emissions standards outlined by the USEPA. The medium and heavy-duty standards adopted by CARB are shown in Table 12.

The USEPA had proposed a Federal Implementation Plan (FIP) with more stringent emissions standards for three California areas with extreme air quality problems but this proposition was overturned early in 1995. The CARB standards outlined in Table 12 will now be applied to all medium- and heavy-duty vehicles in the State of California.

**Table 10: U.S. Environmental Protection Agency  
Heavy-Duty Truck Engine Emission Standards Diesel Cycle (g/bhp-hr)**  
(Source: USEPA)

Model Year	Hydrocarbons (HC)	Carbon Monoxide (CO)	Nitrogen oxides (NO <sub>x</sub> )	Particulates (PM)
1995	1.3	15.5	5.0	0.10
1996	1.3	15.5	5.0	0.10
1997	1.3	15.5	5.0	0.10
1998	1.3	15.5	4.0	0.10

**Table 11: U.S. Environmental Protection Agency  
Heavy-Duty Urban Bus Engine Emission Standards (g/bhp-hr)  
(Source: USEPA)**

Model Year	Hydrocarbons (HC)	Carbon Monoxide (CO)	Nitrogen oxides (NO <sub>x</sub> )	Particulates (PM)
1995	1.3	15.5	5.0	0.07
1996	1.3	15.5	5.0	0.05
1997	1.3	15.5	5.0	0.05
1998	1.3	15.5	4.0	0.05

**Table 12: California Air Resources Board  
Heavy-Duty Urban Bus Engine Emission Standards (g/bhp-hr)  
(Source: CARB)**

Model Year	Hydrocarbons (HC)	Carbon Monoxide (CO)	Nitrogen oxides (NO <sub>x</sub> )	Particulates (PM)
1995	1.3	15.5	5.0	0.07
1996	1.3	15.5	4.0	0.05
1997	1.3	15.5	4.0	0.05
1998	1.3	15.5	4.0	0.05

### **Benefits from the Program**

DOE has provided, and is continuing to provide, a number of benefits to the heavy-duty vehicle and engine market. First, documentation of AFV operation and problems is useful to manufacturers testing a new product. Since one of the points of the demonstration efforts is to find out how a vehicle or component operates before the product is offered for general sale, these problems or issues can be extremely valuable information to the manufacturers.

Second, as the program goes on, it provides the opportunity to develop technical solutions for any problems which do arise. These solutions may be purely hardware in nature, or they may point to procedural changes that are necessary, either involving the vehicles, the refueling systems, or other infrastructural aspects. This problem resolution information is useful to both the manufacturers and fleet operators. An example of successful problem resolution involved DDC, which encountered an injector fouling problem in its development program that was traced to calcium compounds extracted

by methanol from the small amounts of lubricating oil that entered the injectors. This problem was solved by treating the fuel with small amounts of a detergent additive developed by Lubrizol. The additive also provides lubricity and corrosion inhibition and is now used in all alcohol fuels intended for DDC's heavy-duty engines.

Finally, the data collected by the program are made available to users and potential users of AFV technologies for use in their decision-making. Cost and performance data are critical to an operator deciding whether to move toward a new technology, or one trying to decide among various new technologies. In addition, this type of data (emphasizing reliability information) is key to inspiring a level of confidence within fleet organizations, whether they are already involved in AFVs or are merely considering them. Only with detailed data in these areas can future users be convinced that AFVs are available which may truly meet their needs. The Alternative Fuels Data Center has been created specifically to make this kind of information available to the interested public and to manufacturers attempting to judge their research and development efforts as well as identify product improvements areas. Much of the data reported in this paper was obtained from the AFDC.

### **Future Plans and Activities**

As the DOE program continues, collected data will be provided to the AFDC. It is expected that a sizable data base will be developed during this program. A map and a table outlining DOE-funded activities planned for the near future are shown in Figure 5 and Table 13, respectively. As the data are generated, efforts will focus on analysis to convert it into a more useful format for interested parties.

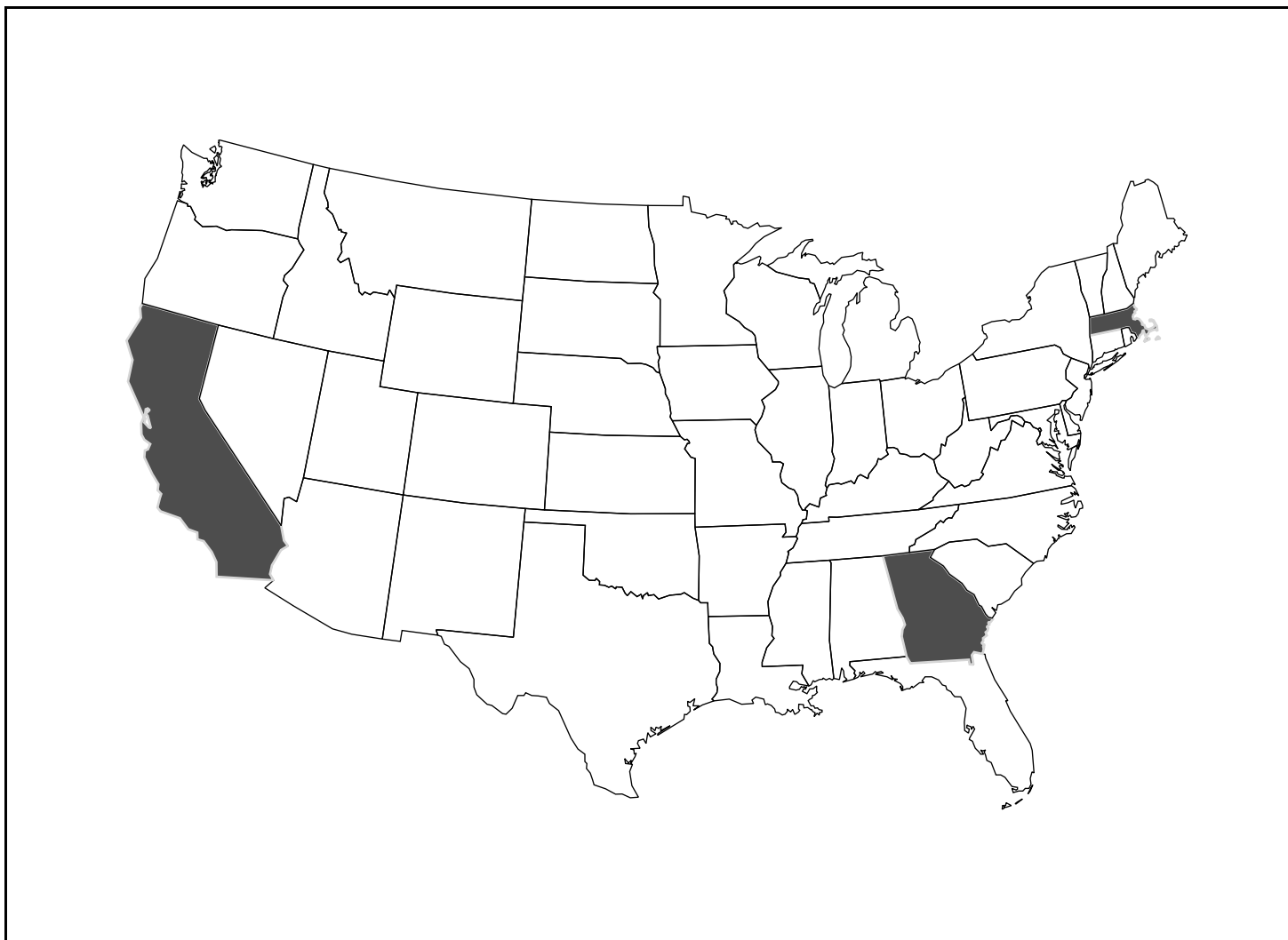
Continuing use is planned for the two West Virginia University Transportable Heavy-Duty Vehicle Emissions Testing Laboratories. The university is under contract to conduct 160 vehicle tests next year. The emission data collected will be reported to the Alternative Fuels Data Center.

Heavy-duty vehicle grants to state and local governments will continue for the foreseeable future. For fiscal year 1996, approximately one million dollars will be available to defray the incremental costs of alternative-fuel heavy-duty vehicles over their conventional counterparts.

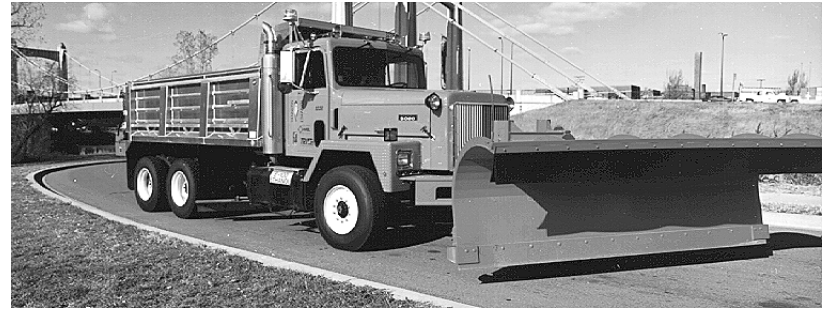
**Table 13: Planned DOE-Funded (American Trucking Association)  
Alternative Fuel Commercial Truck Demonstration Projects**

<b>Operator</b>	<b>Location</b>	<b>Number</b>	<b>Fuel</b>	<b>Status</b>
GWF	California	1	LNG (Mack)	Planned
Browning Ferris Industries	Georgia	1	LNG (Mack)	Planned
Stop and Shop Supermarket	Massachusetts	1	LNG (DDC)	Planned
<b>TOTAL</b>		3.00		

**Figure 5: Map of Planned DOE-Funded Alternative Fuel Heavy-Duty Vehicle Demonstration Projects**







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